Environment Waikato Technical Report 2004/30

# Taupo Emission Inventory 2004

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# Executive Summary

Air quality monitoring in Taupo from 2001 to 2003 has shown concentrations of $PM_{10}$ in excess of the Ministry for the Environment's ambient air quality guideline and National Environmental Standard (NES) of 50 $\mu gm^{-3}$ (24-hour average). Based on 2003 data, the guideline may have been exceeded on 12 days if data are extrapolated for missing values. The NES allows only one exceedence per annum of 50 $\mu g\ m^{-3}$ (24-hour average).

Sources of $PM_{10}$ and other contaminants in Taupo had previously been evaluated for the year 2000 using the emission inventory methodology. This involved a domestic home heating survey and an evaluation of motor vehicle emissions based on a road network model for Taupo. The industrial component relied on a 1997 industrial emissions assessment for the Waikato Region (Noonan, 1997).

This study updates the previous inventory data and includes an assessment of the sources of industrial emissions. Contaminants included were particles ($PM_{10}$ and $PM_{2.5}$), carbon monoxide, nitrogen oxides, sulphur oxides, volatile organic compounds, carbon dioxide and benzene. This report primarily focuses on emissions of particles ($PM_{10}$), as concentrations of $PM_{10}$ in Taupo are in breach of the NES. The $PM_{10}$ sources included in the inventory assessment were domestic heating, motor vehicles, industrial and commercial activities and outdoor burning.

Emissions from domestic home heating were evaluated using the results of a household survey of heating methods. Woodburners and gas were found to be the dominant home heating methods in Taupo being used in the main living area in around 47% and 37% of homes respectively. Electricity was also a common heating method with around 34% of households using that method. Many households used more than one method to heat the main living area of their home.

The main source of $PM_{10}$ and $PM_{2.5}$ emissions in Taupo was domestic home heating, which accounted for around 88% and 90% of total emissions respectively. For $PM_{10}$, the remaining 12% was distributed between motor vehicles (9%), outdoor burning (3%) and industrial emissions (<1%). Motor vehicles also accounted for about half of the CO and $CO_2$ and 90% of the NOx emissions.

# 1 Introduction

Air quality monitoring was carried out in Taupo from 2001 to 2003 using gravimetric sampling. The sampling regime was initially one-day-in-six but was reduced to a one-day-in-three in 2002. During 2003, four guideline exceedences were measured, indicating that around 12 breaches may have occurred if data were extrapolated for missing values. This is greater than the estimate of 6 guideline exceedences for 2002 and is in excess of the air quality guideline for $PM_{10}$ of 50 µg $m^{-3}$ (24-hour average) and the NES for $PM_{10}$ of 50 µg $m^{-3}$, which allows for just one exceedence (MfE, 2004).

Because of the frequency of guideline exceedences in Taupo, an assessment of management measures to achieve the proposed NES is required. This involves an evaluation of sources contributing to existing concentrations as well as likely trends in, and an assessment of management measures, to reduce concentrations.

Previously, a study of sources of emissions of $PM_{10}$ and other contaminants in Taupo had been carried out for the year 2000 based on the results of a home heating survey and road network model for Taupo (Wilton, 2002). The industrial emissions assessment for that study was based on the 1997 study for the Waikato Region (Noonan, 1997). It included a number of estimates of emissions from sources with considerable uncertainty. In particular the estimates of $PM_{10}$ emissions from fugitive dust sources are of concern and may result in an overestimate of the $PM_{10}$ contribution from this source. When these emissions are included in the assessment, the relative contribution of industry to $PM_{10}$ emissions in Taupo is 64%, with 30% from domestic heating and 6% from transport.

This study updates the 2000 emission inventory assessment and includes a revised industrial emissions inventory for Taupo. Results from the inventory will be used to assess management measures for air quality in Taupo.

# 2 Inventory Design

The inventory has been designed with a focus on emissions of $PM_{10}$, although it does include estimates of emissions of other contaminants. Actual monitoring of other contaminants has not been carried out in Taupo, although it is unlikely, based on monitoring carried out in other areas of New Zealand, that concentrations of other indicator contaminants will exceed the proposed NES values or air quality guidelines. One exception may be the air quality guideline for benzo(a)pyrene (BaP) as concentrations of this contaminant have been found to be high in areas where $PM_{10}$ concentrations are elevated as a result of emissions from domestic home heating. No NES has been proposed for BaP at this stage.

## 2.1 Selection of sources

The inventory includes detailed estimates of emissions from domestic heating, outdoor burning, motor vehicles and industry. Emissions from lawn mowers, dust from farming activities and a number of other sources are also discussed in the report.

## 2.2 Selection of contaminants

The inventory included an assessment of emissions of suspended particles ($PM_{10}$), carbon monoxide (CO), sulphur oxides (SOx), nitrogen oxides (NOx), volatile organic compounds (VOC), carbon dioxide ($CO_2$) and fine particles ($PM_{2.5}$).

Emissions of $PM_{10}$, CO, SOx and NOx are included as these contaminants comprise class one air quality indicators as described by MfE (1994) because of their potential for adverse health impacts. Carbon dioxide is typically included in emission inventory investigations in New Zealand to allow for the assessment of regional greenhouse gas $CO_2$ emissions. The finer $PM_{2.5}$ size fraction was also included, as a guideline for $PM_{2.5}$ may be considered by MfE within the next few years.

Volatile organic compounds are typically included in emission inventory investigations because of their potential contribution to the formation of photochemical pollution. These have been retained in the inventory to allow an assessment of emissions of precursors to ozone should future monitoring indicate concentrations of concern.

## 2.3 Selection of areas

The study area was the urban area of Taupo based on the census area unit boundaries for the areas of Rangatira, Nukuhau, Central Taupo, Tauhara, Hilltop, Waipahihi and Richmond Heights (Figure 2.1). This covers the area of greatest impact and allows subsequent assessments of data relative to census information.

The industrial area sited along Centennial Drive is not included as part of this inventory.

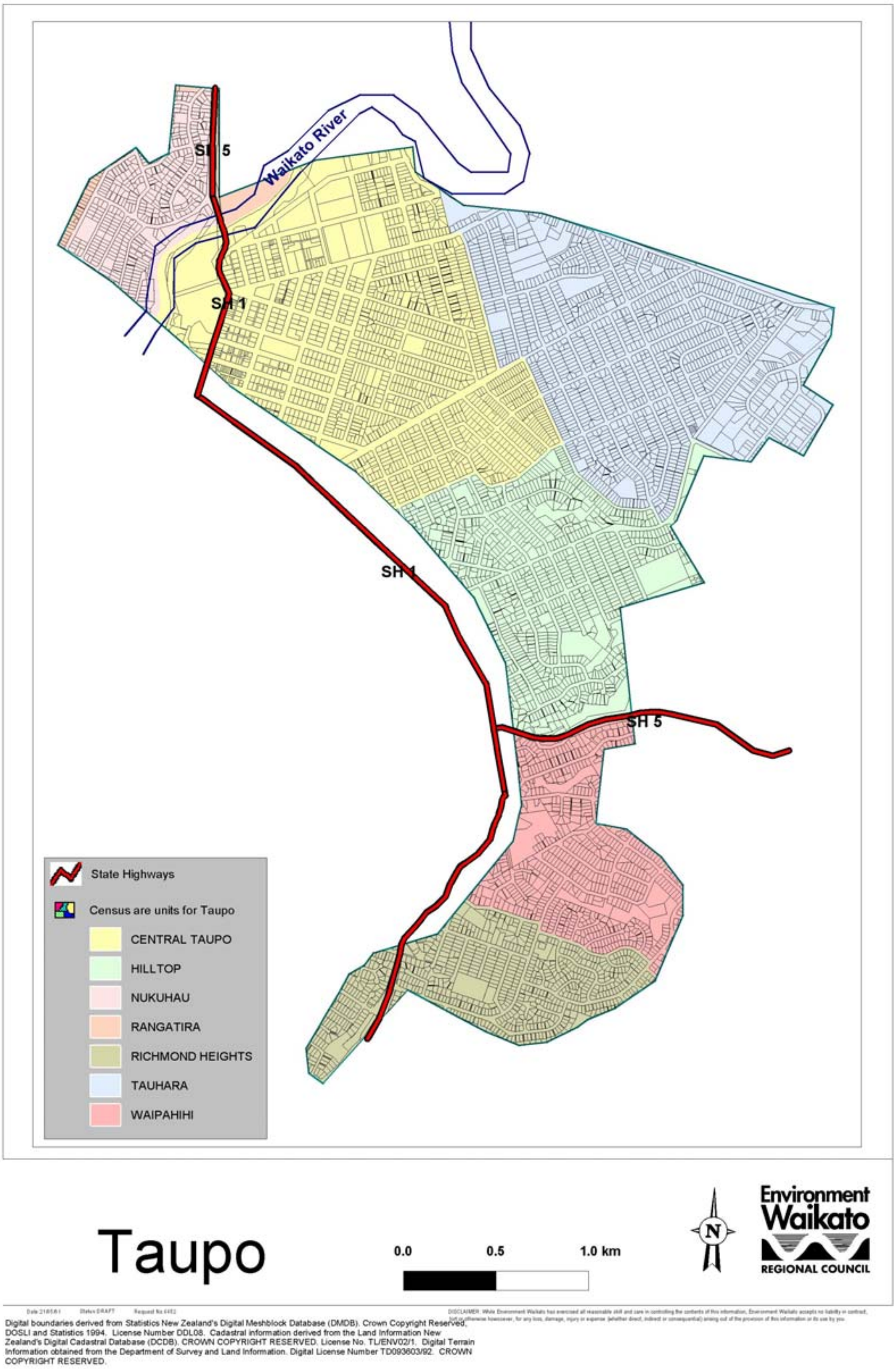


**Figure 2-1: Study area for 2004 Taupo emission inventory**

## 2.4 Temporal distribution

Daily data were collected based on average wintertime emissions and were broken down into the following time of day categories:

- 6am to 10am
- 10am to 4pm
- 4pm to 10pm
- 10pm to 6am

These categories have been used in other emission inventory investigations carried out in New Zealand e.g., Christchurch, Nelson, Hamilton, Dunedin, Timaru and Wellington. They were initially selected to coincide with variations in meteorological conditions that occur at different times of the day for high pollution events, and were based on observations of both pollution and meteorological conditions in Christchurch.

The purpose of collecting data for different time of day periods is to allow for subsequent assessments of the contribution of different sources to concentrations, as opposed to emissions. The latter evaluation requires details on the impact of meteorological conditions on contaminants' concentrations at different times of the day.

# 3 Domestic Heating

## 3.1 Methodology

The domestic heating emission inventory data was collected using a telephone survey of 360 households within the study area during the winter of 2004. The survey was carried out by Digipol during late May and early June 2004 using the emission inventory survey questionnaire shown in Appendix one. Emission factors were then applied to these data to provide an estimate of emissions for the urban areas of Taupo. Summary data for the survey and study area are shown in Table 3.1.

**Table 3-1: Home heating survey area and sample details**

| | Households | Sample size | Area (ha) | Sample error |
|---|---|---|---|---|
| Taupo | 6461 | 366 | 2068 | 5% |

Home heating methods were classified as electricity, open fires, pre 1994 woodburners, 1994-1999 woodburners, post 1999 woodburners, multi-fuel burners, gas burners and oil burners.

The emission factors used to estimate emissions from domestic heating are shown in Table 3.2. These were reviewed for the Taupo 2004 inventory to check that previously used factors were consistent with any more recent testing. As for the 2000 Taupo domestic heating assessment, the open fire and multifuel burner factors were based on the Christchurch 1999 emission factors. The basis for these is detailed in Wilton (2001a). The woodburner emission rates were derived based on an evaluation of types of solid fuel burners installed. The gas and oil $PM_{10}$ emission factors have also been revised as a result of more recent testing in New Zealand (Scott, 2004).

**Table 3-2: Emission factors for domestic heating methods**

| | $PM_{10}$ g/kg | COg/ kg | NOx g/kg | $SO_2$ g/kg | VOC g/kg | $CO_2$ g/kg | $PM_{2.5}$ g/kg |
|---|---|---|---|---|---|---|---|
| **Open fire - wood** | 10 | 100 | 1.6 | 0.2 | 30 | 1600 | 10 |
| **Open fire - coal** | 21 | 80 | 4 | 5.0 | 15 | 2600 | 12 |
| **Pre 1994 burners** | 13 | 130 | 0.5 | 0.2 | 39 | 1800 | 13 |
| **1994-1999 burners** | 6.5 | 65 | 0.5 | 0.2 | 19.5 | 1800 | 6.5 |
| **Post 1999 burners** | 6 | 60 | 0.5 | 0.2 | 18 | 1800 | 6 |
| **Multi-fuel[1] - wood** | 13 | 130 | 0.5 | 0.2 | 39 | 1600 | 13 |
| **Multi-fuel[1] - coal** | 28 | 120 | 1.2 | 3.0 | 15 | 2600 | 12 |
| **Oil** | 0.3 | 0.6 | 2.2 | 3.8 | 0.25 | 3200 | 0.7 |
| **Gas** | 0.03 | 0.18 | 1.3 | 7.6E-09 | 0.2 | 2500 | 0.6 |

[1] - includes potbelly, incinerator, coal range and any enclosed burner that is used to burn coal

One of the assumptions underlying the emissions calculations is the average weight for a log of wood. Average log weights used for inventories in New Zealand have included 1.6 kg, 1.4 kg and more recently 1.9 kg. The latter value is based on a survey of 219 households in Christchurch during 2002 and represents the most comprehensive assessment of average fuel weight. There is some potential for fuel size to vary by region although factors such as appliance design should limit these variations. All three average fuel weight values were derived based on measurements carried out in Christchurch. The 1.9 kg average fuel weight value represents a 19% increase over the year 2000 Taupo emission inventory, which used the initial average fuel weight of 1.6 kg. Compared to the 2000 inventory, the 2004 estimates of emissions from domestic heating will be 19 per cent higher, as a result of a change in methodology.

Emissions for each contaminant and for each time period and season were calculated based on the following equations:

Equation 3.1 **CE (g/day) = EF (g/kg) * FB (kg/day)**

Where:

CE = contaminant emission
EF = emission factor
FB = fuel burnt

Equation 3.2 **CE (g/time period) = EF (g/kg) * FB (kg/time period)**

Where:

CE = contaminant emissions per time period
EF = emission factor

$$\text{FB (kg/time period)} = \frac{\text{no. of hours in time period}}{\text{24hrs}} * \text{total daily fuel use}$$

The main assumptions underlying the emissions calculations are as follows:

- The average weight of a log of wood is 1.9 kg. This weight was based on a diary survey carried out in Christchurch during 2002 (Lamb, 2003).
- The average weight of a bucket of coal is 9 kg.
- That the total daily fuel use (kg) is distributed across the different times of the day based on the number of hours in each time period. For example, if a household indicates that it burns 15 kg wood per day and burns during the periods 4pm-10pm and 6am-10am, it is assumed that 9 kg is burnt in the evening period and 6 kg during the morning period.

## 3.2 Home heating methods

The main methods of home heating in Taupo in 2004 were woodburners (47%), gas (37%) and electricity (34%). Of the households using gas, about half use flued gas and half unflued gas heating (Figure 3.1). Table 3.3 shows that households rely on more than one method of heating their main living area during the winter months.

Wood burning is the most common fuel for households using solid fuel heating methods in Taupo with 58% of households using this fuel. About 62 tonnes of wood is burnt per winter's night. In comparison coal is used by around 2% of Taupo households and around half a tonne is burnt per night.

Only a small proportion (9%) of Taupo residents use open fires to heat their main living area on a typical winter's night and around 3% use multifuel burners.

**Table 3-3: Home heating methods and fuels in Taupo**

| | Heating methods | | Fuel Use | |
|---|---|---|---|---|
| | HH | % | t/day | % |
| Electricity | 2224 | 34% | | |
| | | | | |
| Total Open fire | 583 | 9% | 12 | 13% |
| Open fire - wood | 565 | 9% | 11 | 12% |
| Open fire - coal | 53 | 1% | 0 | 1% |
| Total Woodburner | 3036 | 47% | 76 | 81% |
| Pre 1994 woodburner | 946 | 15% | 22 | 23% |
| 1994-1999 woodburner | 769 | 12% | 16 | 18% |
| Post 1999 woodburner | 1321 | 20% | 38 | 40% |
| Multi-fuel burner | 177 | 3% | 3 | 4% |
| Multi-fuel burner-wood | 177 | 3% | 3 | 3% |
| Multi-fuel burner-coal | 88 | 1% | 0.3 | 0.3% |
| | | | | |
| Gas | 2365 | 37% | 1.9 | 2% |
| Oil | 124 | 2% | 0.5 | 1% |
| Total Wood | 3778 | 58% | 90.2 | 97% |
| Total Coal | 141 | 2% | 0.7 | 1% |
| | | | | |
| **Total** | **6461** | | **93** | |
| | | | | |

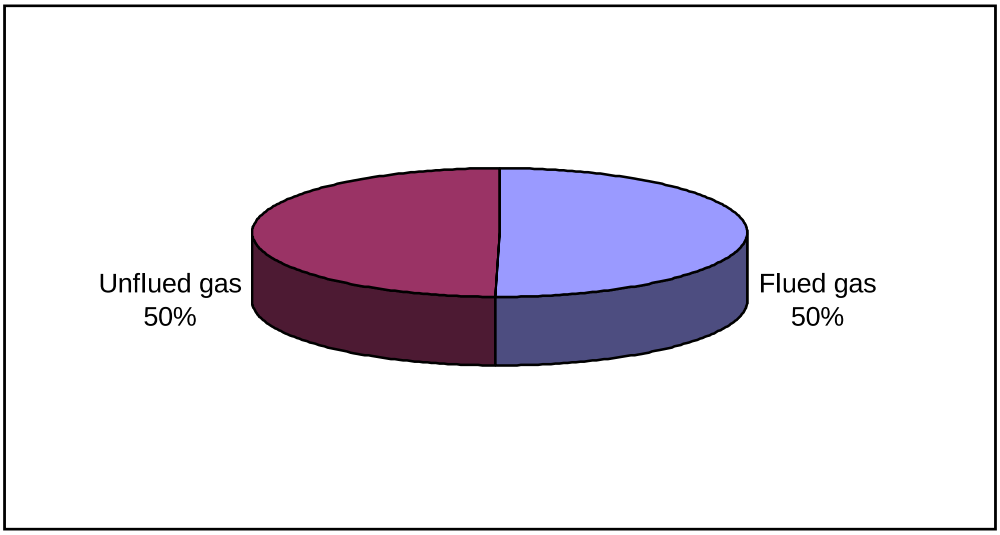


**Figure 3-1: Gas use by appliance type**

## 3.3 Emissions from domestic heating

Tables 3.4 and 3.5 show estimates of emissions from domestic heating in Taupo by time of day. These data are also presented in grams per hectare (g/ha) and as a percentage of the total contaminant emissions in Table 3.6. Results indicate the following:

- About 784 kilograms of $PM_{10}$ is discharged from domestic home heating into the air over Taupo on a typical winter's night/day.
- Of the estimated 784 kilograms of $PM_{10}$ emitted from domestic heating, around 778 kilograms (99%) is in the finer, $PM_{2.5}$ size fraction.
- About 98% of the $PM_{10}$ emissions come from the burning of wood with around 2% from coal and less than 0.1% from gas and oil.
- The main source of $PM_{10}$ from domestic heating is woodburners, which contribute 77% of emissions. Open fires contribute 15% and multifuel burners 6% of the $PM_{10}$ emissions from domestic home heating.
- Wood burning is responsible for the majority of emissions of all contaminants included in the inventory.
- Over half of the $PM_{10}$ emissions occur during the 4pm – 10pm period coinciding with the time of day when meteorological conditions are most likely to be conducive to high pollution.
- The contribution of older (pre 1994) burners to $PM_{10}$ emissions is high (36%) relative to the number of households using them and the quantity of fuel burnt. This is because these burners emit more per kilogram of fuel burnt on average, than most of the other heating methods[1].

[1] With the exception of coal burning on open fires and multifuel burners

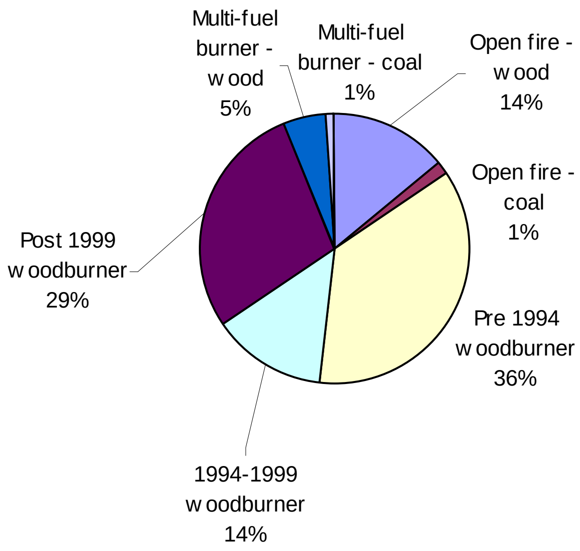


**Figure 3-2: PM10 emissions from different heating methods**

**Table 3-4: Emissions estimates for PM10, CO, NOx and SOx by time of day**

| | Suspended Particulate | | | | | Carbon monoxide | | | | | Nitrogen oxides | | | | | Sulphur oxides | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 6am-10am | 10am-4pm | 4pm-10pm | 10pm-6am | Total $PM_{10}$ (kg) | 6am-10am | 10am-4pm | 4pm-10pm | 10pm-6am | Total CO (kg) | 6am-10am | 10am-4pm | 4pm-10pm | 10pm-6am | Total NOx (kg) | 6am-10am | 10am-4pm | 4pm-10pm | 10pm-6am | Total SOx (kg) |
| **Open fire - wood** | 7 | 13 | 83 | 9 | 112 | 74 | 130 | 828 | 89 | 1121 | 1 | 2 | 13 | 1 | 18 | 0 | 0 | 2 | 0 | 2 |
| **Open fire - coal** | 0 | 0 | 10 | 0 | 10 | 0 | 0 | 38 | 0 | 38 | 0 | 0 | 2 | 0 | 2 | 0 | 0 | 2 | 0 | 2 |
| **Pre 1994 woodburner** | 22 | 43 | 161 | 57 | 284 | 224 | 435 | 1606 | 575 | 2840 | 1 | 2 | 6 | 2 | 11 | 0 | 1 | 2 | 1 | 4 |
| **1994-1999 woodburner** | 12 | 14 | 57 | 24 | 106 | 115 | 136 | 568 | 243 | 1062 | 1 | 1 | 4 | 2 | 8 | 0 | 0 | 2 | 1 | 3 |
| **Post 1999 woodburner** | 27 | 25 | 135 | 39 | 227 | 266 | 255 | 1351 | 394 | 2266 | 2 | 2 | 11 | 3 | 19 | 1 | 1 | 5 | 1 | 8 |
| | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Multi-fuel burner - wood** | 6 | 9 | 16 | 8 | 39 | 63 | 88 | 160 | 84 | 395 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 1 |
| **Multi-fuel burner - coal** | 1 | 1 | 4 | 1 | 7 | 4 | 6 | 17 | 5 | 32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| **Total Wood** | 74 | 104 | 451 | 138 | 768 | 742 | 1044 | 4513 | 1385 | 7683 | 5 | 7 | 36 | 9 | 57 | 2 | 2 | 11 | 3 | 18 |
| **Total Coal** | 0.9 | 1.4 | 13.9 | 1.2 | 17.4 | 4.0 | 6.0 | 54.7 | 5.3 | 69.9 | 0.0 | 0.1 | 2.1 | 0.1 | 2.2 | 0.1 | 0.1 | 2.8 | 0.1 | 3.2 |
| **Oil** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.2 | 0.3 | 0.0 | 0.0 | 0.4 | 0.7 | 1.2 | 0.0 | 0.0 | 0.7 | 1.3 | 2.0 |
| **Gas** | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.0 | 0.2 | 0.0 | 0.3 | 0.6 | 0.3 | 1.4 | 0.1 | 2.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Total** | 75 | 106 | 465 | 140 | 786 | 746 | 1050 | 4568 | 1390 | 7754 | 6 | 8 | 40 | 10 | 63 | 2 | 2 | 14 | 5 | 23 |

Table 3-5: Emissions estimates for VOCs, CO2, and PM2.5 by time of day

| | VOCs | | | | Total VOC (kg) | Carbon dioxide | | | | Total $CO_2$ (t) | $PM_{2.5}$ | | | | $PM_{2.5}$ (kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 6am-10am | 10am-4pm | 4pm-10pm | 10pm-6am | | 6am-10am | 10am-4pm | 4pm-10pm | 10pm-6am | | 6am-10am | 10am-4pm | 4pm-10pm | 10pm-6am | |
| **Open fire - wood** | 22 | 39 | 248 | 27 | 336 | 1 | 2 | 15 | 2 | 20 | 7 | 13 | 83 | 9 | 112 |
| **Open fire - coal** | 0 | 0 | 7 | 0 | 7 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 6 | 0 | 6 |
| **Pre 1994 woodburner** | 67 | 130 | 482 | 172 | 852 | 3 | 6 | 22 | 8 | 39 | 22 | 43 | 161 | 57 | 284 |
| **1994-1999 woodburner** | 35 | 41 | 170 | 73 | 319 | 3 | 4 | 16 | 7 | 29 | 12 | 14 | 57 | 24 | 106 |
| **Post 1999 woodburner** | 80 | 76 | 405 | 118 | 680 | 8 | 8 | 41 | 12 | 68 | 27 | 25 | 135 | 39 | 227 |
| | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Multi-fuel burner - wood** | 19 | 26 | 48 | 25 | 118 | 1 | 1 | 2 | 1 | 5 | 6 | 9 | 16 | 8 | 39 |
| **Multi-fuel burner - coal** | 0 | 1 | 2 | 1 | 4 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 1 | 4 |
| **Total Wood** | 223 | 313 | 1354 | 415 | 2305 | 16 | 21 | 96 | 29 | 162 | 74 | 104 | 451 | 138 | 768 |
| **Total Coal** | 0.5 | 0.7 | 9.2 | 0.7 | 11.1 | 0.1 | 0.1 | 1.6 | 0.1 | 1.9 | 0.5 | 0.8 | 7.9 | 0.7 | 9.9 |
| **Oil** | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 | 0.6 | 1.1 | 1.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Gas** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.1 | 0.6 | 2.6 | 0.3 | 4.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 |
| **Total** | 223 | 314 | 1363 | 416 | 2316 | 18 | 22 | 100 | 31 | 171 | 75 | 105 | 459 | 139 | 778 |

**Table 3-6: Taupo summary emissions by appliance type**

| | Fuel Use | | $PM_{10}$ | | CO | | | | $NO_x$ | | | $SO_x$ | | | VOC | | | $CO_2$ | | | $PM_{2.5}$ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | t/day | % | kg | g/ha | % | kg | g/ha | % | kg | g/ha | % | kg | g/ha | % | kg | g/ha | % | t | kg/ha | % | kg | g/ha | % |
| **Open fire** | 11.7 | 13% | 122 | 59 | 16% | 1159 | 561 | 15% | 20 | 10 | 31% | 5 | 2 | 20% | 344 | 166 | 15% | 21 | 10 | 13% | 118 | 57 | 15% |
| **Open fire - wood** | 11.2 | 12% | 112 | 54 | 14% | 1121 | 542 | 14% | 18 | 9 | 28% | 2 | 1 | 10% | 336 | 163 | 15% | 20 | 10 | 12% | 112 | 54 | 14% |
| **Open fire - coal** | 0.5 | 1% | 10 | 5 | 1% | 38 | 18 | 0% | 2 | 1 | 3% | 2 | 1 | 10% | 7 | 3 | 0% | 1 | 1 | 1% | 6 | 3 | 1% |
| **Total woodburner** | 75.9 | 81% | 617 | 298 | 78% | 6167 | 2982 | 80% | 38 | 18 | 60% | 15 | 7 | 65% | 1850 | 895 | 80% | 137 | 66 | 80% | 617 | 298 | 79% |
| **Pre 1994 woodburner** | 21.8 | 23% | 284 | 137 | 36% | 2840 | 1373 | 37% | 11 | 5 | 17% | 4 | 2 | 19% | 852 | 412 | 37% | 39 | 19 | 23% | 284 | 137 | 36% |
| **1994-1999 woodburner** | 16.3 | 18% | 106 | 51 | 14% | 1062 | 513 | 14% | 8 | 4 | 13% | 3 | 2 | 14% | 319 | 154 | 14% | 29 | 14 | 17% | 106 | 51 | 14% |
| **Post 1999 woodburner** | 37.8 | 40% | 227 | 110 | 29% | 2266 | 1095 | 29% | 19 | 9 | 30% | 8 | 4 | 33% | 680 | 329 | 29% | 68 | 33 | 40% | 227 | 110 | 29% |
| **Total multi-fuel burner** | 3.3 | 4% | 47 | 23 | 6% | 426 | 206 | 6% | 2 | 1 | 3% | 1 | 1 | 6% | 122 | 59 | 5% | 6 | 3 | 4% | 44 | 21 | 6% |
| **Multi-fuel burner-wood** | 3.0 | 3% | 39 | 19 | 5% | 395 | 191 | 5% | 2 | 1 | 2% | 1 | 0 | 3% | 118 | 57 | 5% | 5 | 3 | 3% | 39 | 19 | 5% |
| **Multi-fuel burner-coal** | 0.3 | 0% | 7 | 4 | 1% | 32 | 15 | 0% | 0 | 0 | 0% | 1 | 0 | 3% | 4 | 2 | 0% | 1 | 0 | 0% | 4 | 2 | 1% |
| **Gas** | 1.9 | 2% | 0 | 0 | 0% | 0 | 0 | 0% | 2 | 1 | 4% | 0 | 0 | 0% | 0 | 0 | 0% | 5 | 2 | 3% | 0 | 0 | 0% |
| **Oil** | 0.5 | 1% | 0 | 0 | 0% | 0 | 0 | 0% | 1 | 1 | 2% | 2 | 1 | 9% | 0 | 0 | 0% | 2 | 1 | 1% | 0 | 0 | 0% |
| **Total wood** | 90 | 97% | 768 | 371 | 98% | 7683 | 3715 | 99% | 57 | 28 | 91% | 18 | 9 | 78% | 2305 | 1114 | 100% | 162 | 78 | 95% | 768 | 371 | 99% |
| **Total coal** | 1 | 1% | 17 | 8 | 2% | 70 | 34 | 1% | 2 | 1 | 3% | 3 | 2 | 14% | 11 | 5 | 0% | 2 | 1 | 1% | 10 | 5 | 1% |
| **Total** | 93 | | 786 | 380 | | 7754 | 3749 | | 63 | 31 | | 23 | 11 | | 2316 | 1120 | | 171 | 82 | | 778 | 376 | 0% |

# 4 Motor Vehicles

## 4.1 Methodology

Assessing emissions from motor vehicles involves collecting data on vehicle kilometres travelled (VKT) under different levels of congestion, and the application of emission factors to these data. In Taupo, a road network model has been developed to estimate VKTs travelled in the area under different levels of congestion. The model was updated in 2002 with VKTs and emissions estimates made by Dave Hunter from Gabites Porter for the year 2000 and for the year 2021 with two estimates of the latter made based on a “do nothing” and a “do minimum” scenario for traffic management. Emission estimates for Taupo for 2004 were based on the 2000 road network model and the 2021 “do minimum” scenario.

### 4.1.1 Emission factors

The emission factors used to estimate motor vehicle emissions for $PM_{10}$, CO, NOx and VOC were taken from the New Zealand Traffic Emission Rates (NZTER) database based on a vehicle fleet profile derived from motor vehicle registrations for Taupo (Table 4.1). The percentages of different vehicles are similar to the national vehicle fleet profile for 1998 described in the Ministry of Transport’s Vehicle Fleet Emission Control Strategy (Table 4.2). The NZTER database was developed by the Ministry of Transport (MOT) based on measured emissions rates from actual vehicle emissions tests on New Zealand vehicles under various road/traffic conditions. Emission rates for SOx and $CO_2$ are not included in the NZTER database and were selected based on emission rates derived by the Fuel and Energy Group for the national vehicle fleet profile.

Benzene emission factors were derived based on a weight fraction of motor vehicle VOC emissions from the Australian National Pollutant Inventory. These were 6.58% for petrol vehicles, 1.01% for diesel vehicles and 0.943% for LPG vehicles. These data were apportioned using the Taupo vehicle fleet profile. Because of differences in the composition of New Zealand and Australian petrol, these data should be treated as rough estimates that provide an indication of order of magnitude only.

The emission factors for $PM_{2.5}$ were based on estimates of $PM_{10}$ emissions using data from the British Colombia Lower Fraser Valley adjusted for the Taupo vehicle fleet profile. This indicated that around 64% of the $PM_{10}$ tailpipe emissions would be in the $PM_{2.5}$ size fraction in the Taupo area. In addition to tailpipe emissions, $PM_{10}$ from the wearing of brakes and tyres were also included in the emissions assessments. Emission factors for $PM_{10}$ and $PM_{2.5}$ from these sources were also derived from the British Colombia Lower Fraser Valley data adjusted for the Taupo vehicle fleet profile. However, the extent to which these conversions based on overseas data are applicable to New Zealand vehicle emissions is uncertain. Consequently emission estimates for $PM_{2.5}$ from motor vehicles and $PM_{10}$ from the wearing of tyre and brakes should be treated with caution.

**Table 4-1: Vehicle registrations in Taupo (December 2000)**

| | Petrol | Diesel | LPG | Other | Total |
|---|---|---|---|---|---|
| Cars | 10,822 | 1118 | 5 | 5 | 11,950 |
| Light commercial vehicle | 1,279 | 1276 | 5 | | 2,560 |
| Bus | 23 | 66 | 4 | | 93 |
| Heavy truck | 13 | 515 | <0.1 | | 528 |
| Miscellaneous | 32 | 182 | 1 | | 215 |
| Motorcycle | 283 | | | | 283 |
| Total | 12,452 | 2,975 | 15 | 5 | 15,446 |
| Percentage | 80.6% | 19.3% | 0.1% | 0.0% | 100% |

**Table 4-2: New Zealand vehicle fleet profile from MOT (1998)** [2]

| | Petrol | Diesel | CNG | LPG | Electric | Total |
|---|---|---|---|---|---|---|
| Cars | 1798000 | 103100 | 280 | 640 | | 1902020 |
| LCV | 212000 | 148600 | 130 | 230 | | 360960 |
| Bus | 600 | 6600 | 80 | 170 | 1200 | 8650 |
| Heavy truck | 3200 | 68000 | 280 | 330 | | 71810 |
| Miscellaneous | 6200 | 18600 | | | | 24800 |
| Motorcycle | 79000 | | | | | 79000 |
| Total | 2099000 | 344900 | 770 | 1370 | 1200 | 2447240 |
| Total percentage | 85.8% | 14.1% | 0.0% | 0.1% | 0.0% | 100.0% |

Emission factors for Taupo were selected based on "suburban" type driving and for three different driving conditions called Levels Of Service (LOS). The LOS categories are a representation of traffic congestion in a road corridor and include free flow (LOS category A-B), interrupted flow (LOS category C-D) and congested (LOS category E-F). The latter LOS category was not relevant for the year 2000 but some category E-F LOS were estimated for 2021.

The emission factors for each contaminant and each LOS category for Taupo for 2004 are shown in Table 4.3. The NZTER derived emission rates are based on 30% of the VKTs occurring under cold start conditions.

**Table 4-3: Taupo emission factors for 2004 based on a suburban driving regime**

| | CO g/km | VOC g/km | NOx g/km | $PM_{10}$ g/km | SOx g/km | $CO_2$ g/km | Benzene g/km |
|---|---|---|---|---|---|---|---|
| Congested (E-F) | 21.43 | 3.09 | 1.41 | 0.20 | 0.23 | 447.33 | 0.17 |
| Interrupted (C-D) | 17.91 | 2.53 | 1.38 | 0.16 | 0.19 | 386.17 | 1.38E-01 |
| Free flow (A-B) | 15.20 | 2.41 | 1.28 | 0.14 | 0.18 | 346.16 | 1.31E-01 |

### 4.1.2 Vehicle kilometres travelled

The daily vehicle kilometres travelled (VKT) in Taupo for 2000 and 2021 were calculated by Gabbites Porter using the TRACKs road network modelling system. In this model, road corridors within the study area are identified by means of a co-ordinate system and referred to as road links. The volume of traffic on the road for each road link for any given hour is represented by one of four one-hour time slots called AM, PM, IP and EV.

[2] Ministry of Transport, 1998, Vehicle fleet emission control strategy – final report. Ministry of Transport.

The model estimates the number of vehicles in each of the road links for each of these time slots. The number of vehicles is then multiplied by the link distance to give the vehicle kilometres travelled (VKT) for each time period. A level of service value (A-B, C-D, E-F) is allocated to each VKT estimate (for each road link and time of day category) based on the ratio of volume of traffic to the capacity of the road link to sustain motor vehicles.

Table 4.4 shows the number of VKT for each of the different time periods, for each of the different levels of congestion for 2000 and 2021. These were calculated by combining the one-hour periods AM, PM, EV and IP as follows:

- 6am-10am: (2xAM +2xEV)
- 10am-4pm: (5.75 x IP)
- 4pm-10pm: (2xPM+1.25xIP+2.75xEV)
- 10pm-6am: (2.5xEV)

The extrapolated 2004 values are shown in Table 4.5.

**Table 4-4: VKT breakdown by time of day and LOS for Taupo for 2000 and 2021**

| | **Total VKT** | **Time of day** | | | |
|---|---|---|---|---|---|
| **2000** | | **6am-10am** | **10am-4pm** | **4pm-10pm** | **10pm-6am** |
| A-B | 428636 | 80126 | 180988 | 138567 | 28955 |
| C-D | 17622 | 3558 | 5615 | 8449 | 0 |
| E-F | 0 | | | | |
| **Total** | 446,258 | 83684 | 186603 | 147016 | 28955 |
| | **Total VKT** | **Time of day** | | | |
| **2021** | | **6am-10am** | **10am-4pm** | **4pm-10pm** | **10pm-6am** |
| A-B | 459822 | 86,260 | 193,246 | 149,386 | 30,931 |
| C-D | 59494 | 12,911 | 23,668 | 22,915 | 0 |
| E-F | 326 | 326 | 0 | 0 | 0 |
| **Total** | 519642 | 99497 | 216913 | 172301 | 30931 |

**Table 4-5: VKT breakdown by time of day and LOS for Taupo for 2004**

| | **Total VKT** | **Time of day** | | | |
|---|---|---|---|---|---|
| **2004** | | **6am-10am** | **10am-4pm** | **4pm-10pm** | **10pm-6am** |
| A-B | 572092 | 108341 | 237372 | 188336 | 38043 |
| C-D | 59494 | 12911 | 23668 | 22915 | 0 |
| E-F | 1500 | 1500 | 0 | 0 | 0 |
| **Total** | 633085 | 122752 | 261040 | 211251 | 38043 |

Emissions for the year 2004 were estimated by multiplying the VKT estimates in Table 4.5 by the emission factors shown in Table 4.3. Equation 4.1 shows the calculation used to determine the amount of emissions for each time period.

*Equation 4.1 Emissions(g)=Emission Factor (g/km) * VKT (km)*

The emissions over a 24-hour period were calculated by totalling the emissions calculated during the four emission inventory time-periods.

## 4.2 Motor vehicle emissions

In Taupo around 520,000 vehicle kilometres are estimated to be travelled per day during 2004. Traffic conditions are relatively free flowing and the majority of the VKTs occur during the 10am to 10pm periods.

Around 83 kilograms of $PM_{10}$ is estimated to be produced as a result of vehicle emissions in Taupo. Of this 76 kg is estimated to be from tailpipe emissions with 3kg from brake wear and 4kg from tyres (Figure 4.1). Based on overseas emission data adjusted for the Taupo vehicle fleet, approximately 64% of the tailpipe and 100% of the brake and tyre wear $PM_{10}$ emissions are in the finer $PM_{2.5}$ size fraction. If these data are applicable to motor vehicle emissions in New Zealand, about 72% of the $PM_{10}$ emissions from motor vehicles are likely to be in the finer $PM_{2.5}$ size fraction.

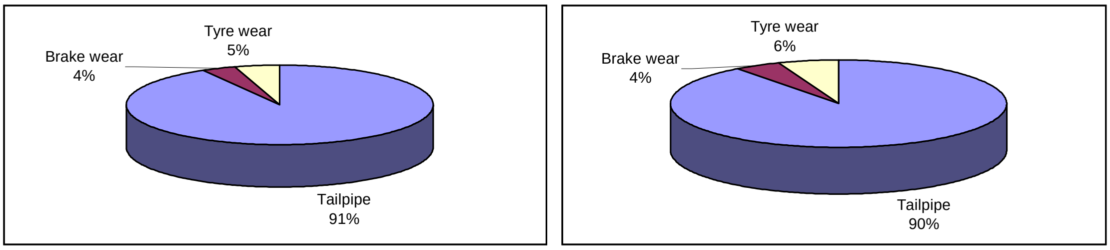


**Figure 4-1: Breakdown of PM10 (left) and PM2.5 (right) emissions from motor vehicles**

Figure 4.2 shows variations in motor vehicle $PM_{10}$ emissions in Taupo by time of day. The majority of the emissions occur during the daytime (10am-4pm) time period and evening periods with smaller contributions occurring during the morning (20%) and night time (6%) periods.

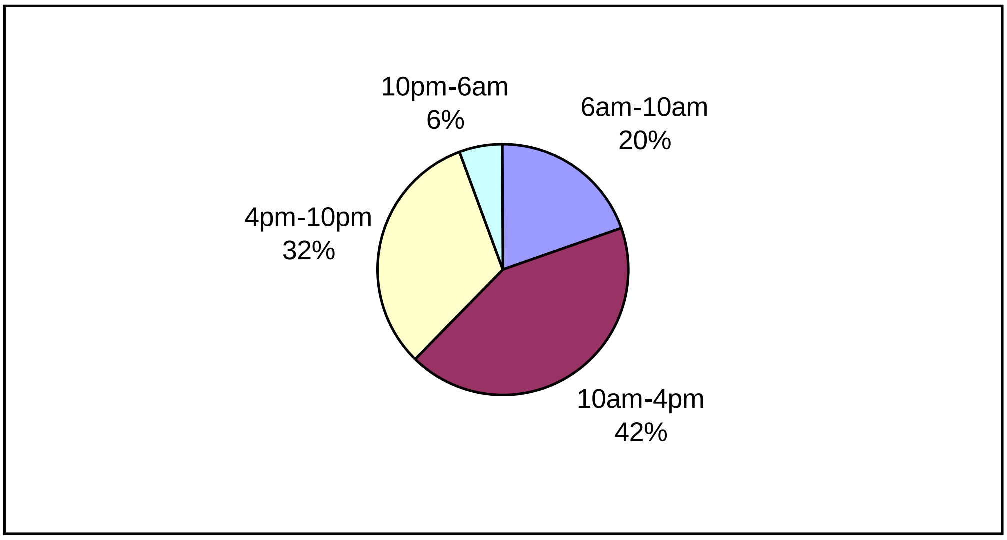


**Figure 4-2: Daily variations in PM10 emissions from motor vehicles**

Other contaminant emissions from motor vehicles in Taupo include around 8 tonnes of CO, 672kg of NOx and 92kg of SOx. In comparison, in Christchurch, where CO concentrations exceed ambient air quality guidelines at least once during most winters, motor vehicles emit around 109 tonnes of CO within the main urban area.

Tables 4.6 and 4.7 show emissions from motor vehicles in Taupo by time of day and by weight and grams per hectare respectively.

**Table 4-6: Emissions from motor vehicles by time of day**

| | $PM_{10}$ | | | | CO | | | | | | NOx | | | | | SOx | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 6am-10am | 10am-4pm | 4pm-10pm | 10pm-6am | $PM_{10}$ (kg) | 6am-10am | 10am-4pm | 4pm-10pm | 10pm-6am | CO (kg) | 6am-10am | 10am-4pm | 4pm-10pm | 10pm-6am | NOx (kg) | 6am-10am | 10am-4pm | 4pm-10pm | 10pm-6am | SOx (kg) |
| **Taupo** | 16 | 35 | 27 | 5 | 83 | 1549 | 3361 | 2681 | 40 | 8061 | 129 | 280 | 223 | 40 | 672 | 18 | 39 | 31 | 40 | 92 |
| | VOC | | | | | $CO_2$ | | | | | $PM_{2.5}$ | | | | | | | | | |
| | 6am-10am | 10am-4pm | 4pm-10pm | 10pm-6am | VOC (kg) | 6am-10am | 10am-4pm | 4pm-10pm | 10pm-6am | $CO_2$ (t) | 6am-10am | 10am-4pm | 4pm-10pm | 10pm-6am | $PM_{2.5}$ (kg) | | | | | |
| **Taupo** | 241 | 525 | 417 | 74 | 1258 | 35 | 76 | 61 | 11 | 182 | 12 | 26 | 18 | 3 | 60 | | | | | |

**Table 4.7: Summary of motor vehicle emissions in Taupo**

| | | $PM_{10}$ | | | CO | | | NOx | | | SOx | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Hectares** | **kg** | | **g/ha** | **kg** | | **g/ha** | **kg** | | **g/ha** | **kg** | | **g/ha** |
| **Taupo** | 2068 | 83 | | 40 | 8061 | | 3898 | 672 | | 325 | 92 | | 45 |
| | | **VOC** | | | $CO_2$ | | | $PM_{2.5}$ | | | | | |
| | **Hectares** | **kg** | | | **t** | | **kg/ha** | **kg** | | **g/ha** | | | |
| **Taupo** | 2068 | 1258 | | | 182 | | 88 | 60 | | 29 | | | |

# 5 Industrial and Commercial

## 5.1 Methodology

Only a small number of industries in the Taupo area are required to hold a resource consent for a discharge to air. The majority of these are located to the northeast of the urban area of Taupo (Figure 5.1) and are not within the study area shown in Figure 2.1. Based on the topography of the area, it would seem unlikely that emissions from these industries would contribute to $PM_{10}$ concentrations measured in the main urban area of Taupo and hence these have not been included in this inventory.

Thus industrial emissions within the study area are limited to a small number of minor activities. These activities were identified using school lists, the Taupo phone book and through consultation with the Taupo District Council. The methodology used to estimate emissions from these activities involved the collection of data relating to the process e.g., boiler, referred to as activity data and the application of emission factors to these data. Activity data were collected through contact with local industrial and commercial activities and local schools. The selection of industries for inclusion in the inventory was primarily based on potential for $PM_{10}$ emissions. Industrial activities such as spray painting or dry cleaning operations, which discharge primarily volatile organic compounds (VOC) were not included in the assessment.

Emissions from one consented activity and several non-consented industrial/commercial discharges were included in the assessment. The types of discharges included incineration/crematorium and small coal and gas boilers.


**Figure 5-1: Location of industries with discharge to air consents in and around Taupo**

The combustion emissions were estimated using emission factor data as indicated in Equation 5.1.

Equation 5.1 Emissions (kg) = Emission factor (kg/tonne) x Fuel use (tonnes)

The emission factors used to estimate the quantity of emissions discharged are shown in Table 5.1. The coal fired boiler emission factors for $PM_{10}$ are based on coal research limited emission factors. Emission factors for $PM_{2.5}$ are based on the USEPA AP42 database[3] particle size distribution factors, as are emission factors for $PM_{10}$ from wood fired boilers and diesels and CO, NOx and SOx. The VOC and $CO_2$ emission factors are based on factors derived by NIWA for the Christchurch 1996 emission inventory (NIWA, 1998).

**Table 5-1: Emission factors for industrial discharges**

| | $PM_{10}$ g/kg | $PM_{2.5}$ g/kg | CO g/kg | NOx g/kg | $SO_2$ g/kg | VOC g/kg | $CO_2$ g/kg |
|---|---|---|---|---|---|---|---|
| Coal boiler (underfeed stoker) | 3.1 | 1.9 | 5.5 | 4.8 | 13.5 | 0.1 | 2400 |
| Diesel boiler | 0.47 | 0.11 | 0.67 | 3.24 | 10.5 | 0.2 | 3194 |
| | $g/m^3$ | $g/m^3$ | $g/m^3$ | $g/m^3$ | $g/m^3$ | $g/m^3$ | $g/m^3$ |
| Natural gas | 0.12 | 0.12 | 1.34 | 1.6 | 0.0096 | 0.088 | 1920 |

## 5.2 Industrial and commercial emissions

Table 5.2 shows an estimated one kg of $PM_{10}$ per day during the winter months from industrial and commercial activities in the urban areas of Taupo. It should be noted when considering emissions of $CO_2$ and VOCs that emissions from geothermal activities have not been included in the assessment. These are located outside of the urban area, although generally closer than the industries located around Centennial Drive and do not emit significant amounts of $PM_{10}$.

[3] http://www.epa.gov/ttn/chief/ap42/index.html

**Table 5.2: Summary of Taupo industrial/ commercial emissions**

| | | $PM_{10}$ | | CO | | NOx | | SOx | |
|---|---|---|---|---|---|---|---|---|---|
| | Hectares | kg | g/ha | kg | g/ha | kg | g/ha | kg | g/ha |
| | | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 1 |
| | | VOC | | $CO_2$ | | $PM_{2.5}$ | | | |
| | Hectares | kg | g/ha | kg | g/ha | kg | g/ha | | |
| | | 0 | **0** | 1 | **0** | 0 | **0** | | |

**Table 5-2: Industrial/commercial emissions for Taupo by time of day**

| | Suspended Particulate – $PM_{10}$ | | | | | Suspended Particulate - $PM_{2.5}$ | | | | | Carbon monoxide | | | | | Nitrogen oxides | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 6am-10am | 10am-4pm | 4pm-10pm | 10pm-6am | $PM_{10}$ (kg) | 6am-10am | 10am-4pm | 4pm-10pm | 10pm-6am | $PM_{2.5}$ (kg) | 6am-10am | 10am-4pm | 4pm-10pm | 10pm-6am | CO (kg) | 6am-10am | 10am-4pm | 4pm-10pm | 10pm-6am | NOx (kg) |
| | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 2 |
| | Sulphur oxides | | | | | Volatile organic compounds | | | | | Carbon dioxide | | | | | | | | | |
| | 6am-10am | 10am-4pm | 4pm-10pm | 10pm-6am | SOx (kg) | 6am-10am | 10am-4pm | 4pm-10pm | 10pm-6am | VOC (kg) | 6am-10am | 10am-4pm | 4pm-10pm | 10pm-6am | $CO_2$ (t) | | | | | |
| | 1 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | | | | | |

# 6 Outdoor burning

Emissions from outdoor burning can contribute to $PM_{10}$ and $PM_{2.5}$ concentrations. In some urban areas of New Zealand outdoor burning is prohibited because of the adverse health and nuisance effects associated with these emissions. Outdoor burning includes any backyard burning of household or garden wastes in a drum, incinerator or open air. Presently there are no regulations restricting outdoor burning in Taupo, although section 17 of the Resource Management Act (1991) or section 29 of the Health Act could be used to control these emissions if individual discharges were causing adverse effects.

## 6.1 Methodology

Emissions from outdoor burning during the winter months were estimated for Taupo based on data collected for the 2004 Taupo domestic home heating emission survey. This data indicated that outdoor burning was carried out by around 4% of households in Taupo, burning an average of around 5 fires per winter per household. The proportion of green waste (60%) versus household rubbish burnt (40%) was based on data collected in Otago (ESR, 1999). Emissions were calculated based on the assumption of an average weight of material per burn of 174kg and using the emission factors in Table 6.1.

**Table 6-1: Outdoor burning emission factors (AP42,2002)**

| | $PM_{2.5}$ g/kg | $PM_{10}$ g/kg | CO g/kg | NOx g/kg | SOx g/kg | VOC g/kg | $CO_2$ g/kg |
|---|---|---|---|---|---|---|---|
| Garden rubbish | 8 | 8 | 42 | 3 | 0.5 | 4 | 1470 |
| Household rubbish | 17 | 19 | 42 | 3 | 0.5 | 4.278 | 1470 |
| **Emission factor** | 11.7 | 12.5 | 42.0 | 3.0 | 0.5 | 4.3 | 1470 |

## 6.2 Emissions from outdoor burning

Outdoor burning emission estimates for Taupo (Table 6.2) indicate that around 17 kg of $PM_{10}$ from outdoor burning could be expected per day during the winter months. Of this, the majority (93%) is within the finer, $PM_{2.5}$ size fraction. Outdoor burning also produces around 58 kg of carbon monoxide and around 2031 tonnes of carbon dioxide per day during winter.

It should be noted, however, that there are a number of uncertainties relating to this estimation. In particular it is assumed that burning is carried out evenly throughout the winter, whereas in reality it is highly probable that a disproportionate amount of burning is carried out during weekend days. Thus on some days no $PM_{10}$ from outdoor burning may occur and on other days it might be many times the amount estimated in this assessment.

**Table 6-2: Outdoor burning emission estimates for Taupo by time of day**

| | $PM_{2.5}$ kg | $PM_{10}$ kg | CO kg | NOx kg | SOx kg | VOC kg | $CO_2$ kg |
|---|---|---|---|---|---|---|---|
| **6am-10am** | 4 | 4 | 15 | 1 | 0 | 1 | 4 |
| **10am-4pm** | 12 | 13 | 44 | 3 | 1 | 4 | 12 |
| **4pm-10pm** | | | | | | | |
| **10pm-6am** | | | | | | | |
| **Nelson - total** | | | | | | | |

# 7 Other sources of emissions

The major sources of $PM_{10}$ and other contaminants during the winter months when $PM_{10}$ concentrations are high in Taupo are likely to result from domestic home heating, outdoor burning, motor vehicles and industry.

Other sources of emissions not included in the inventory include dusts ($PM_{10}$) and vegetation, which can emit VOC and NOx. Neither of these latter contaminants is likely to be an air quality concern in Taupo and vegetation is unlikely to be a significant source in the predominantly urban area of Taupo. A natural emissions inventory for the Waikato Region was prepared in 1999 and includes estimates of emissions from vegetative sources (NIWA, 1999).

Emissions of $PM_{10}$ from wind blown dusts from the erosion of soils and from the tilling of land are also potential contributors. Some contribution from the more rural areas surrounding Taupo is possible. Some anecdotal evidence also suggests that the pumice soils of Taupo may give rise to greater natural dust emissions than soil types in other parts of New Zealand. Limited emission data available for tilling suggests around 1.26 kg $PM_{10}$ and 0.6 kg $PM_{2.5}$ is produced per hectare tilled (GVRD, 1998). Thus if 10 hectares were being tilled in or near to the Taupo area, emissions might be in the order of 12 kilograms of $PM_{10}$ and 6 kg of $PM_{2.5}$. The contribution from re-suspension of natural dusts from activities other than tilling is largely unknown.

Lawn mowers, leaf blowers and chainsaws can also contribute small amounts of particulate. These are not typically included in emission inventory studies owing to the relatively small contribution, particularly in areas where solid fuel burning is a common method of home heating. Based on data for other areas, $PM_{10}$ emissions from lawn mowing in Taupo are likely to be less than 3 kg per day[4].

[4] ESR (1999) indicates an average of around 3 kg per day of $PM_{10}$ emissions from lawn mowing for Dunedin

# 8 Total Emissions

Domestic heating is the main source of $PM_{10}$ and $PM_{2.5}$ emissions in Taupo during the winter months, contributing around 88% of $PM_{10}$ and 90% of the $PM_{2.5}$. Of the domestic $PM_{10}$ emissions, older (pre-1994) woodburners contribute around one third of the emissions, with open fires contributing 15%. Figure 8.1 shows that the other 12% of the total $PM_{10}$ emissions come from a combination of motor vehicles (9%) and outdoor burning (3%). Industry within the urban area contributes less than 1% of the $PM_{10}$ emissions in Taupo township.

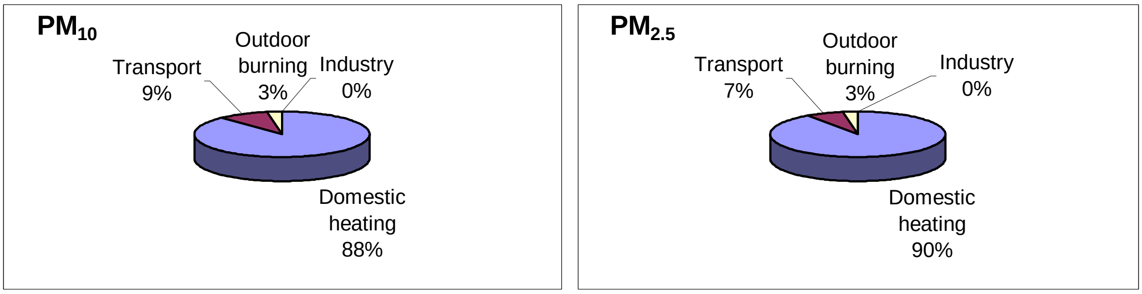


**Figure 8-1: Relative contribution of sources to PM10 and PM2.5 emissions in Taupo**

The majority of the $PM_{10}$ emissions occur during the evening (4pm to 10pm) time period (Figure 8.2). This is likely to coincide with the time of day when meteorological conditions are most conducive to elevated pollution levels as temperature inversions and low wind speeds typically occur during the evening period. Emissions that occur during times when meteorological conditions are conducive to elevated pollution will have a greater impact on 24-hour average concentrations than emissions that occur when wind speeds are elevated.

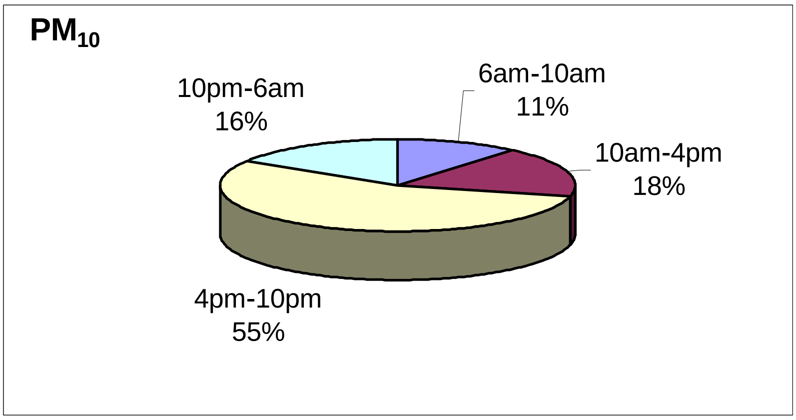


**Figure 8-2: PM10 emissions in Taupo by time of day**

The total quantities of emissions for each contaminant and the breakdown of emissions by time of day are shown in Tables 8.1 and 8.2.

These suggest that around 895 kilograms of $PM_{10}$ are discharged into the air over Taupo per day during the winter months. This compares to around 750 kilograms per day in Tokoroa, around two tonnes per day in Nelson and around 8 tonnes in Christchurch. The majority (96%) of the $PM_{10}$ in Taupo is estimated to be in the $PM_{2.5}$ size fraction, although natural sources not included in this assessment may have a greater proportion of $PM_{10}$ in the coarser ($PM_{10}$-$PM_{2.5}$) size fraction. Other potential sources of $PM_{10}$ emissions not included in the detailed emissions assessment are discussed in chapter seven. A basic analysis suggests that the contribution of sources identified and assessed in that section is likely to be less than 30 kg, although this does not include an assessment of the contribution of natural dusts from activities other than tilling.

Motor vehicles are the main source of CO, $CO_2$, NOx and SOx.

**Table 8-1: Relative contribution of different sources to contaminant emissions**

| | $PM_{10}$ | $PM_{2.5}$ | CO | NOx | SOx | VOC | $CO_2$ |
|---|---|---|---|---|---|---|---|
| **Domestic heating** | 88% | 90% | 49% | 9% | 20% | 65% | 48% |
| **Motor vehicle** | 9% | 7% | 51% | 90% | 78% | 35% | 51% |
| **Outdoor burning** | 3% | 3% | 1% | 1% | 1% | 0% | 1% |
| **Industry** | <1% | <1% | <1% | <1% | 2% | <1% | <1% |

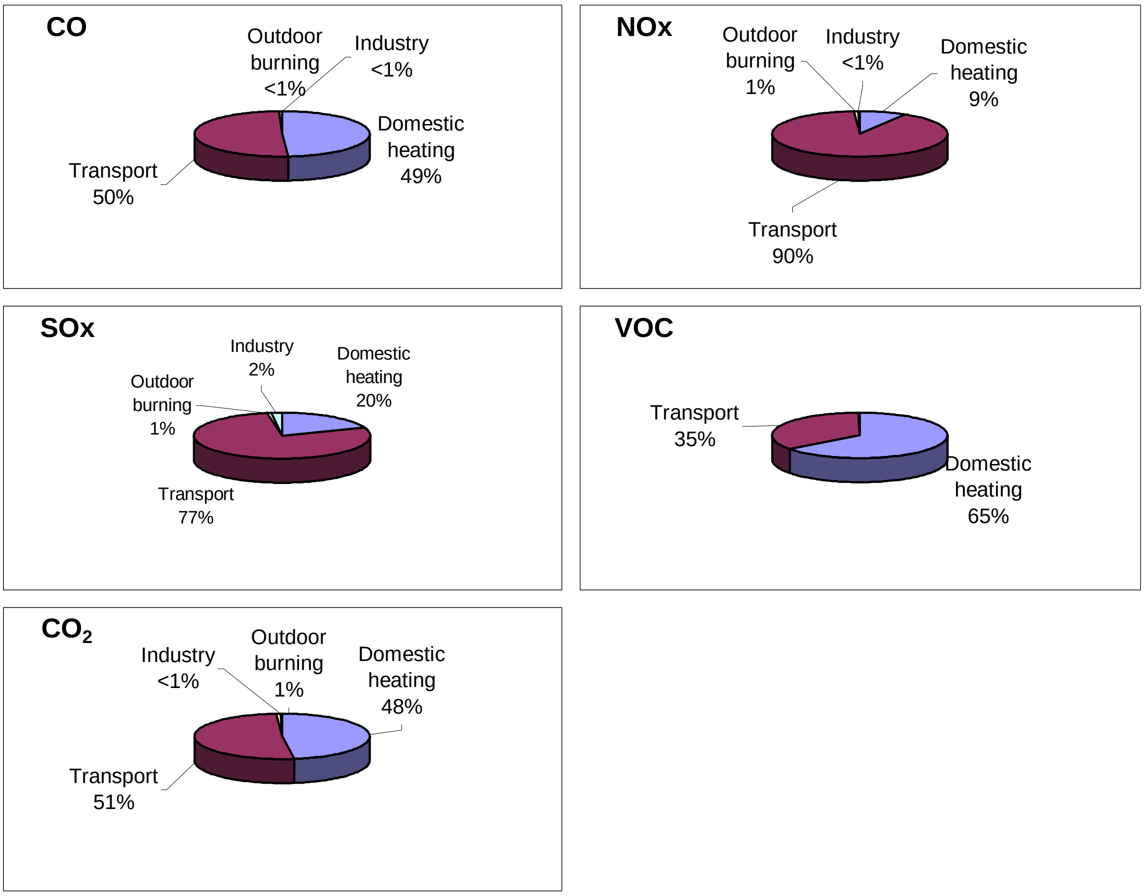


**Figure 8-3: Relative contribution of sources to contaminant emissions**

**Table 8-2: Total emissions by time of day for Taupo**

| Total emissions (kg) | 6am-10am | 10am-4pm | 4pm-10pm | 10pm-6am | Total $PM_{10}$ kg | 6am-10am | 10am-4pm | 4pm-10pm | 10pm-6am | Total $PM_{2.5}$ kg | 6am-10am | 10am-4pm | 4pm-10pm | 10pm-6am | Total CO (kg) | 6am-10am | 10am-4pm | 4pm-10pm | 10pm-6am | Total NOx (kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Domestic heating | 75 | 106 | 465 | 140 | 786 | 75 | 105 | 459 | 139 | 778 | 746 | 1050 | 4568 | 1390 | 7754 | 6 | 8 | 40 | 10 | 63 |
| Motor vehicle | 16 | 35 | 27 | 5 | 83 | 12 | 26 | 18 | 3 | 60 | 1549 | 3361 | 2681 | 40 | 8061 | 129 | 280 | 223 | 40 | 672 |
| Outdoor burning | 6 | 19 | | | 25 | 6 | 18 | | | 23 | 21 | 63 | | | 84 | 1 | 4 | | | 6 |
| Industry | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 2 |
| Total | 98 | 160 | 492 | 144 | 895 | 93 | 149 | 478 | 142 | 862 | 2317 | 4474 | 7249 | 1430 | 15900 | 137 | 294 | 263 | 50 | 743 |

| Total emissions (kg) | 6am-10am | 10am-4pm | 4pm-10pm | 10pm-6am | Total SOx (kg) | 6am-10am | 10am-4pm | 4pm-10pm | 10pm-6am | Total VOC (kg) | 6am-10am | 10am-4pm | 4pm-10pm | 10pm-6am | Total $CO_2$ (t) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Domestic heating | 2 | 2 | 14 | 5 | 23 | 223 | 314 | 1363 | 416 | 2316 | 18 | 22 | 100 | 31 | 171 |
| Motor vehicle | 18 | 39 | 31 | 40 | 92 | 241 | 525 | 417 | 74 | 1258 | 35 | 76 | 61 | 11 | 182 |
| Outdoor burning | 0 | 1 | | | 1 | 2 | 6 | | | 9 | 1 | 2 | | | 3 |
| Industry | 1 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Total | 21 | 43 | 45 | 45 | 119 | 466 | 845 | 1781 | 491 | 3583 | 54 | 100 | 161 | 41 | 357 |

**Table 8-3: Total emissions by time of day per hectare for Taupo**

| | 6am-10am | 10am-4pm | 4pm-10pm | 10pm-6am | Total $PM_{10}$ g/ha | 6am-10am | 10am-4pm | 4pm-10pm | 10pm-6am | Total $PM_{2.5}$ g/ha | 6am-10am | 10am-4pm | 4pm-10pm | 10pm-6am | Total CO g/ha | 6am-10am | 10am-4pm | 4pm-10pm | 10pm-6am | Total NOx g/ha |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Domestic heating | 36 | 51 | 225 | 68 | 380 | 36 | 51 | 222 | 67 | 376 | 361 | 507 | 2209 | 672 | 3749 | 3 | 4 | 19 | 5 | 31 |
| Motor vehicle | 8 | 17 | 13 | 2 | 40 | 6 | 13 | 9 | 2 | 29 | 749 | 1625 | 1296 | 19 | 3689 | 62 | 136 | 108 | 19 | 325 |
| Outdoor burning | 3 | 9 | 0 | 0 | 12 | 3 | 8 | 0 | 0 | 11 | 10 | 30 | 0 | 0 | 41 | 1 | 2 | 0 | 0 | 3 |
| Industry | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Total | 47 | 77 | 238 | 70 | 433 | 45 | 72 | 231 | 69 | 417 | 1120 | 2163 | 3505 | 692 | 7480 | 66 | 142 | 127 | 24 | 359 |

| | 6am-10am | 10am-4pm | 4pm-10pm | 10pm-6am | Total SOx g/ha | 6am-10am | 10am-4pm | 4pm-10pm | 10pm-6am | Total VOC g/ha | 6am-10am | 10am-4pm | 4pm-10pm | 10pm-6am | Total $CO_2$ kg/ha |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Domestic heating | 1 | 1 | 7 | 2 | 11 | 108 | 152 | 659 | 201 | 1120 | 9 | 11 | 49 | 15 | 82 |
| Motor vehicle | 9 | 19 | 15 | 19 | 61 | 117 | 254 | 202 | 36 | 608 | 17 | 37 | 29 | 5 | 88 |
| Outdoor burning | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 0 | 4 | 0 | 1 | 0 | 0 | 1 |
| Industry | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 10 | 21 | 22 | 22 | 74 | 226 | 409 | 861 | 237 | 1732 | 26 | 49 | 78 | 20 | 172 |

# References


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# **Appendix One:** Home Heating Questionnaire

1. (a) Do you use an **OPEN FIRE** in your house on a TYPICAL Winter's day or night?
**YES ( ) NO ( )** *If* NO ***GO TO Question*** 3.

(b) Do you use it:

i. In the morning (between 6am and 10 am) **YES ( ) NO ( )**
ii. Day time (between 10am and 4pm) **YES ( ) NO ( )**
iii. Evening (between 4pm and 10pm) **YES ( ) NO ( )**
iv. Overnight (between 10pm and 6am) **YES ( ) NO ( )**

(c) Do you use wood on your open fire? **YES () NO *If NO GO TO Part (f)***

(d) How much wood do you use per day? ***(ask them how many pieces*** of ***wood (logs) they use on an average Winter's day. Better would be KG/DAY):*** ________________

(e) Do you buy your wood from a wood merchant or collect it yourself? **BUY IT ( )**
**COLLECT IT ( ) BOTH ( )** *If* **BOTH ask %Collected ______ % Bought ______**

(f) Do you use coal on your open fire? **YES ( ) NO ( )** *If* NO ***GO TO Question*** 2.

(g) How much coal do you use per day? ***(ask them how many buckets*** of ***coal they use on an average Winter's day. Better would be KG/DAY):*** ________________

(h) What type of coal do you use? ________________

2. (a) Do you use any type of **ELECTRICAL HEATING** in your house on a TYPICAL winter's day or night? **YES ( ) NO ( )** ***If*** NO ***GO TO Question 3.***

(b) Do you use it

i. In the morning (between 6am and 10 am) **YES ( ) NO ( )**
ii. Day time (between 10 am and 4pm) **YES ( ) NO ( )**
v. Evening (between 4pm and 10 pm) **YES ( ) NO ( )**
vi. Overnight (between 10 pm and 6am) **YES ( ) NO ( )**

3. (a) Do you use any type of **GAS HEATING** in your house on a TYPICAL winter's day or night?
**YES ( ) NO ( )** *If NO GO TO Question 4*.

(b) Is it flued or unflued gas heating? **FLUED ( ) UNFLUED ( ) BOTH ( )**

(c) Do you use it:

i. In the morning (between 6am and 10 am) **YES ( ) NO ( )**
ii. Day time (between 10 am and 4pm) **YES ( ) NO ( )**
vii. Evening (between 4pm and 10pm) **YES ( ) NO ( )**
viii. Overnight (between 10pm and 6am) **YES ( ) NO ( )**

(d) How much gas do you use ***?(ask them for the size of the gas bottle(s) and how often they would refill them*** -(sizes are 2kg, 2.5kg, 3kg, 4.5kg, 9kg, 18kg, 20kg, 45k, 90kg)

Size#*1* ________________ Freq# 1 ________________
Size#2 ________________ Freq# 2 ________________

4. (a) Do you use a **LOG BURNER**? ***(This is not a multifuel burner ie does not burn coal)*** in your house on a TYPICAL Winter's day or night. **YES ( ) NO ( )** *If* ***NO GO TO Question 5.***

(b) How old is your log burner? 10 yrs+ ( ) 5- 10 yrs old ( ) Less than 5 yrs ( )

(c) What type of wood burner:

Make: ________________

Model: ________________

(d) Do you use it:

i. In the morning (between 6am and 10 am) **YES ( ) NO ( )**
ii. Day time (between 10 am and 4pm) **YES ( ) NO ( )**
ix. Evening (between 4pm and 10 pm) **YES ( ) NO ( )**
x. Overnight (between 10 pm and 6am) **YES ( ) NO ( )**

(e) How much wood do you use per day? ***(ask them how many pieces of wood (logs) they use on an average winter's day. Better would be KG/DAY):*** ______________________________

(f) Do you buy your wood from a wood merchant or collect it yourself? **BUY IT ( ) COLLECT IT ( ) BOTH ( )** *If* **BOTH ask %Collected ______ % Bought ______**

5. (a) Do you use a burner which burns coal as well as wood - ie a **MULTI FUEL BURNER** ***(This includes incinerators, pot belly stoves, McKay space heaters etc.)*** in your house on a TYPICAL winter's day or night? **YES ( ) NO ( )** ***If*** NO ***GO TO Question 6***

(b) How old is your multi fuel burner? 10 yrs+ ( ) 5- 10 yrs old ( ) Less than 5 yrs ( )

(c) What type of multi fuel burner is it? ______________________________

(d) Do you use it

i. In the morning (between 6am and 10 am) **YES ( ) NO ( )**
ii. Day time (between 10am and 4pm) **YES () NO ( )**
xi. Evening (between 4pm and 10pm) **YES () NO ( )**
xii. Overnight (between 10pm and 6am) **YES ( ) NO ( )**

(e) How much wood do you use per day? ***(ask them how many pieces of wood (logs) they use on an average winters day. Better would be KG/DAY):*** ______________________________

(f) Do you buy your wood from a wood merchant or collect it yourself? **BUY IT ( )**
**COLLECT IT ( )**
**BOTH ( )** *If* **BOTH ask %Collected ______% Bought ______**

(g) Do you use coal on your multi fuel burner? **YES () NO ( )** *If NO GO TO Question 6.*

(h) How much coal do you use per day? ***(ask them how many buckets of coal they use on an average Winter's day. Better would be KG/DAY):*** ______________________________

(i) What type of coal do you use?

6. (a) Do you use an **OIL FIRED HEATING** system in your house on a TYPICAL Winter's day or night? **YES ( ) NO( )** ***If*** NO ***GO TO*** END.

(b) Do you use it:

i. In the morning (between 6am and 10 am) **YES ( ) NO ( )**
ii. Day time (between 10am and 4pm) **YES () NO ( )**
xiii. Evening (between 4pm and 10pm) **YES () NO ( )**
xiv. Overnight (between 10pm and 6am) **YES ( ) NO ( )**

(c) How much oil do you use? ______________________(litres)